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ARGENTINA CORN YIELD MODEL

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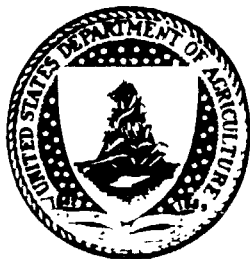
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16. Abstract <p>A model based on multiple regression was developed to estimate corn yields for the country of Argentina. A meteorological data set was obtained for the country by averaging data for stations within the corn-growing area. Predictor variables for the model were derived from monthly total precipitation, average monthly mean temperature, and average monthly maximum temperature. A "trend variable" was included for the years 1965 to 1980 since an increasing trend in yields due to technology was observed between these years.</p>					
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INTRODUCTION

The purpose of this study was to select monthly weather variables that could be used to estimate yields of the Argentina corn crop. The corn-growing area in Argentina is indicated in Figure 1. Most of Argentina's corn is grown in a concentrated area in central Argentina where the climate is predominantly humid subtropical. The western edge of the soybean area in central Cordoba is semi-arid with warm to hot summers. There drought and high temperatures can be a problem during the growing season which begins with planting in October and November and extends to harvest in April through June.

METHOD

Multiple regression analysis of yield with selected agroclimatic indices was used to derive a suitable model. The regression equation for the corn model derived is:

$$\hat{Y} = \alpha + B_1T + B_2 (ETMETH_i) + B_3 (TX_i) + E$$

where

\hat{Y} = Estimated yield

α = Constant

B_j = Coefficients of the variables $j = 1 - 3$

T = Trend 1965-1980

$ETMETH_i = ET - \hat{ET}$ for month i : where $\hat{ET} = K \cdot PET$ and $K = \overline{ET}/\overline{PET}$.

TX_i = Maximum temperature for month i , and

E = Unexplained error.

Trend between the years 1965 and 1980 was determined from a plot of yields as shown in Figure 2. ET (evapotranspiration) minus \hat{ET} (climatically appropriate evapotranspiration) was used as an index representing soil moisture for plant growth. A more complete definition is given in the Appendix. Large positive $ET - \hat{ET}$ values suggest wet conditions.

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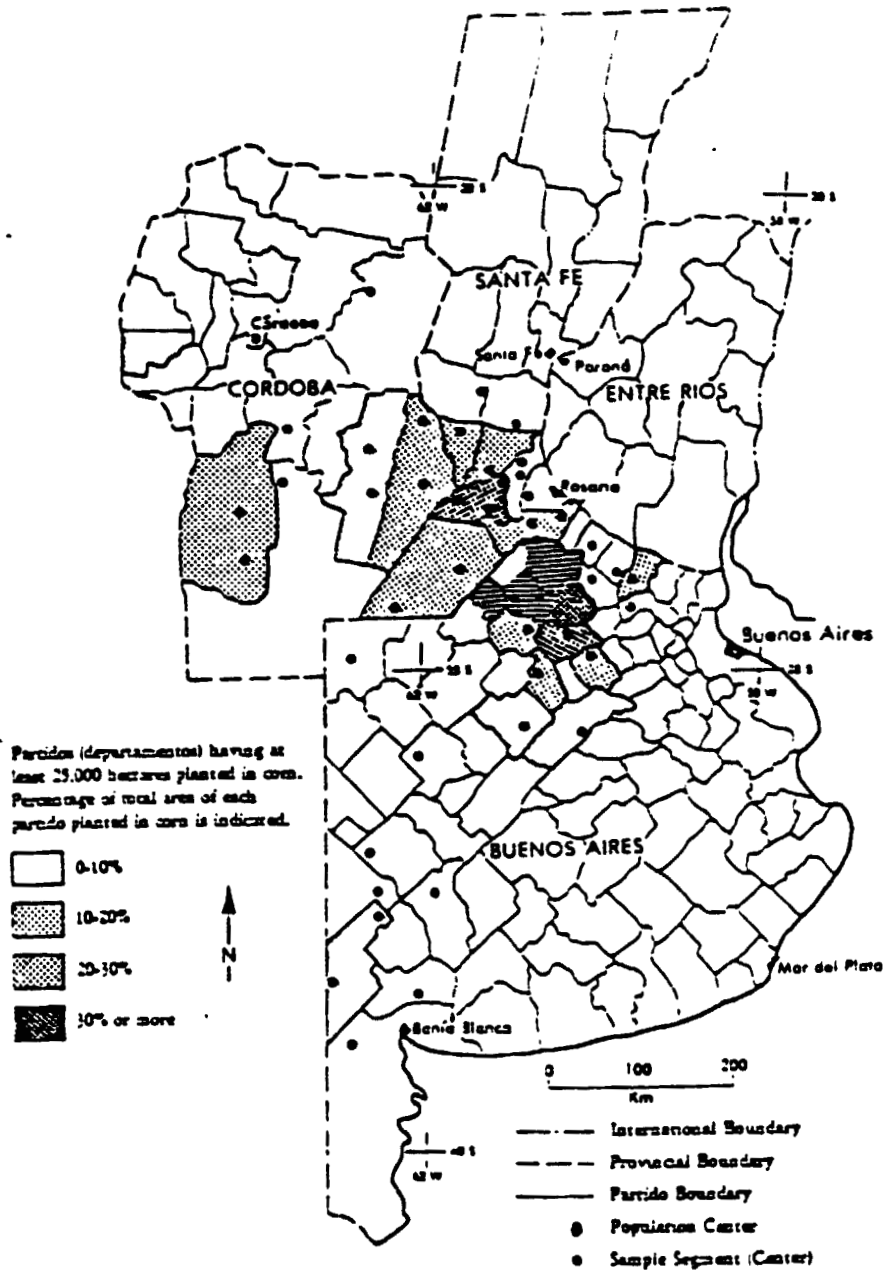
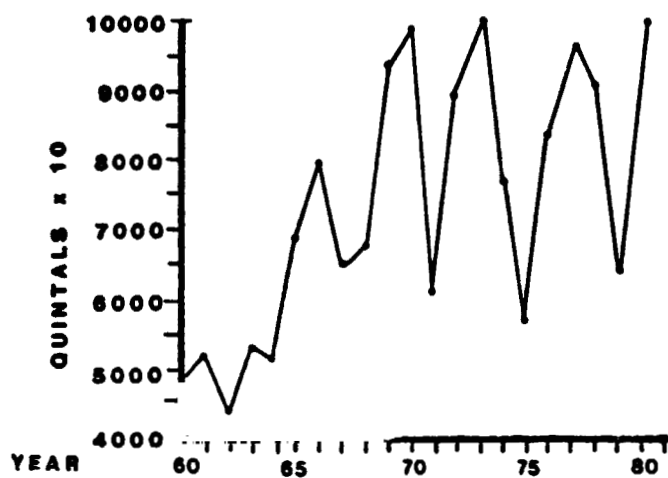
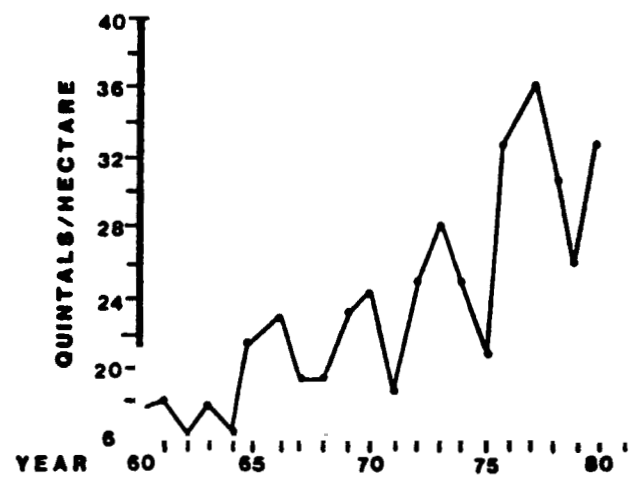


Figure 1. DENSITY OF PLANTED AREA IN CORN 1977/78 CROP YEAR
 (Source: "Agronomic Characterization of the Argentina Indicator Region")

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CORN PRODUCTION



CORN YIELDS

Figure 2. Plots of Production and Yield Versus Year for Argentina Corn.

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In developing the models, various procedures of the Statistical Analysis System (SAS Institute, Inc., 1979) were used. The procedures used and the operations performed with each are summarized in the Appendix. The selected model had the highest R^2 and included variables that were significant at the 10 per cent level and were agronomically meaningful.

DATA

Crop data for Argentina from 1960 to 1979 was obtained from the Foreign Agricultural Service (Alan Vandagrith, personal communication, 1982). A data set was created with year of yield as year of planting. Since the growing season spans two numerical years, the crop data was expressed in terms of "year + 1" (or harvested year) and the meteorological data corresponding to any yield included data for that year and "lagged" data for the previous year.

The meteorological data was created using the general Argentina meteorological station file. This file was composed of data from several different sources, including the Monthly Climatic Data for the World and the Servicio Meteorological Nacional in Argentina (R.E. Jensen, C.M. Sakamoto, and S.E. Mummert; August, 1974). Stations inside the corn-producing area were averaged by province and weighted according to the percentage that their province contributed to the entire country's production. Figure 3 shows the corn-growing area in Argentina and associated stations; Table 1 lists the stations used and their weights.

The years between 1961 and 1980 (year of harvest) were used in the model since these years contained the most complete meteorological data.

PROCEDURES

Weather variables were selected from correlations and plots with yield. These variables, along with TREND, were tried in regression equations. The limited number of data years severely limits the number of variables that

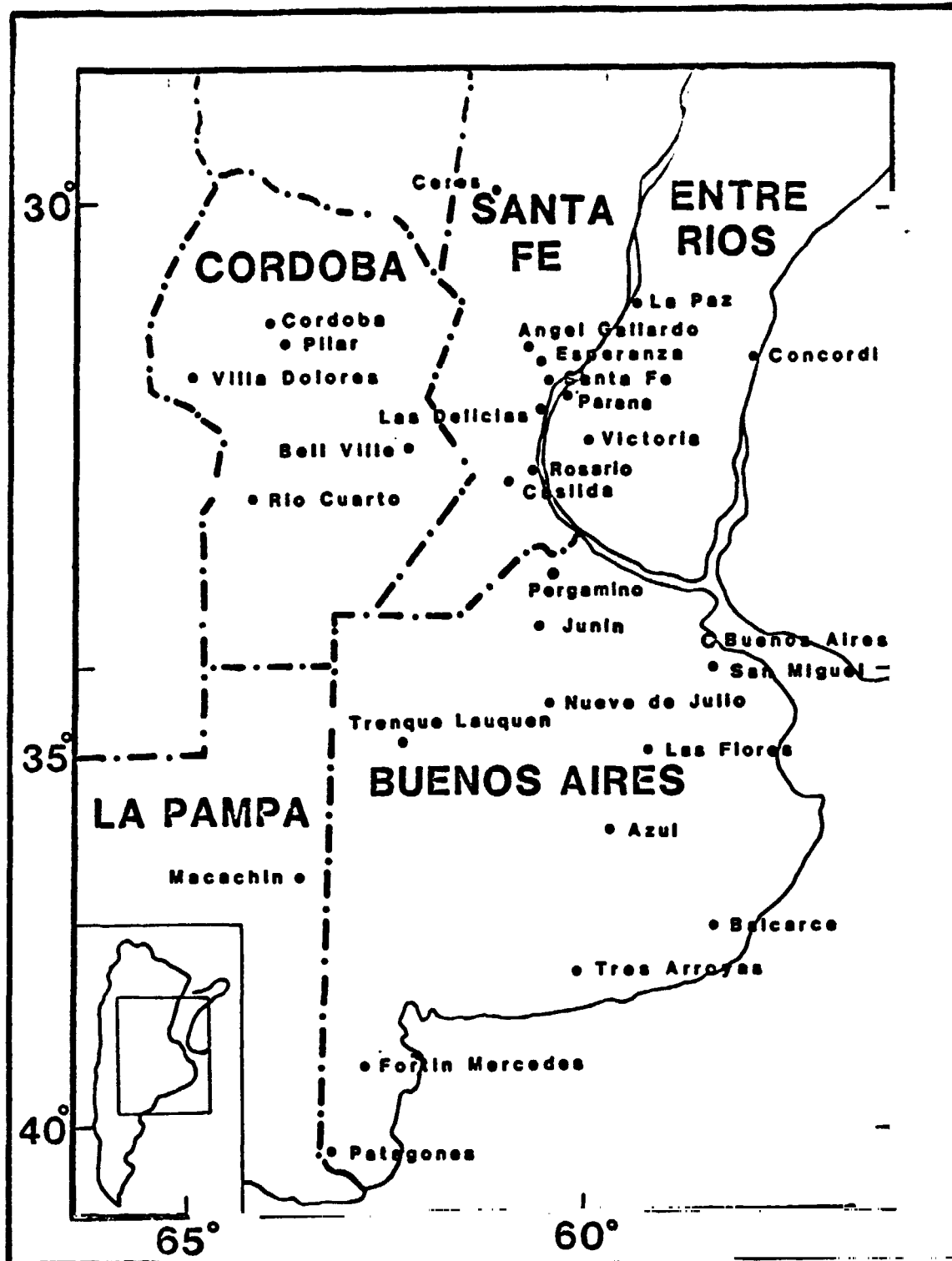


Figure 3. Five major agricultural provinces in Argentina

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<u>STATION NAME</u>	<u>WEIGHT</u>
BUENOS AIRES	.50
Pergamino	
Junin	
Nueve de Julio	
CORDOBA	.27
Rio Cuarto	
Bell Ville	
SANTA FE	.23
Rosario	
Casilda	
Las Delicias	
Parana	
Pergamino	

Table 1. Meteorological Stations Used
for the Argentina Corn Model.

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can be included in a regression model by limiting the number of degrees of freedom. This influenced the choice of model considered "best" for soybeans. Three weather variables plus TREND were considered the optimum model with 19 years of data. The three weather variables are:

ETMETH11.....ET - \hat{ET} for November

TX12.....Maximum temperature for December

TX1.....Maximum temperature for January.

The coefficient for the November variable was positive which reflects moisture requirements just after planting. The coefficients for maximum temperature for December and January were negative indicating that temperatures too high in the peak summer months during the tasselling and silking stages lead to stress on the plant. There is a critical growth period for corn. The statistics of the selected model are summarized in Table 2.

TEST RESULTS

A jackknife test was run on the model. In this test a year was eliminated from the crop data and the model was used to predict that year's yield. This process was done for each successive year beginning with 1961. The results were reasonable with the greatest difference (3.24 quintals) between predicted and actual yield in 1976. That year severe drought badly damaged the corn crop and harvest was hampered by rains. Test results are printed on Table 3 and plotted on Figure 4.

APPENDIX

Definition of Variables

The difference between \hat{ET} and ET is an index of the amount of moisture available for plant growth. Soil moisture depletion is based on evapotranspiration (ET) estimates, determined as follows:

$$(ET)_n = \frac{(S)_{n-1}}{AWC} [\{ (PET)_n - (P)_n \} + (P)_n]$$

where

$(ET)_n$ = "Actual" evapotranspiration,

$(S)_{n-1}$ = Available moisture at end of $n-1$ month,

AWC = Maximum water holding capacity,

$(P)_n$ = Precipitation for month n , and

$(PET)_n$ = Potential evapotranspiration for month n .

$\hat{ET} - ET$ measures the difference between the actual evapotranspiration and the "climatically appropriate" evapotranspiration, giving an indication of soil moisture supply and demand.

Statistical Analysis System Procedures Used

PROC CORR	Computes correlation coefficients between variables, including Pearson product-moment and weighted product-moment correlation.
PROC PLOT	Graphs one variable against another, producing a printer plot.
PROC STEPWISE	Provides five methods for stepwise regression. Stepwise is useful when selecting variables to be included in a regression model from a collection of independent variables.
PROC STEPWISE FORWARD	Begins by finding the one-variable model that produces the highest R^2 . For each of the other independent variables, FORWARD calculates F-statistics reflecting the contribution to the model if the variable were to be included.

PROC STEPWISE BACKWARD

Begins by calculating statistics for a model including all the independent variables. The variables are deleted from the model one by one until all the remaining variables produce F-statistics significant at the .10 level.

PROC STEPWISE STEPWISE

The stepwise method is a modification of the forward selection technique, differing in that variables already in the model do not necessarily stay there. After a variable is added (as in the forward selection method) the stepwise method looks at all the variables already included in the model and deletes any variable that does not produce an F-statistic significant at the .10 level. Only after this check is made and the necessary deletions accomplished can another variable be added to the model.

PROC STEPWISE MAXR

(Maximum R^2 improvement) Unlike the three techniques above, this method does not settle on a single method. Instead it looks for the "best" two-variable model, the "best" three variable model, and so forth.

PROC PETM

Uses latitude and mean monthly temperature to calculate Thornthwaite's potential evapo-transpiration for each month.

PROC ZINDEX

Uses monthly PET's, precipitation, SS (beginning moisture in surface layer), AWCS (available water capacity in surface layer, SU (beginning moisture in the underlying layer), and AWCU (available water capacity in the underlying layer) to calculate Palmer's soil moisture budget, drought index Z, ET, and \bar{ET} .

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BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES ENTERED D SQUAD = 0.87889714 C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
DEVIATION	9	151.29895507	37.82471902	14.13	0.0001
TOTAL	14	20.46504394	2.04650439		
		172.16400000			
	R VALUE		TYPE III SS		PROB>F
	STD ERROR		F		
INTERCEPT	71.45	14162	44.59797920	21.29	0.0007
DEVIATION	0.79	7433	7.90865410	3.79	0.0402
DEVIATION	0.52	2337	8.91427400	4.27	0.0655
DEVIATION	-0.52	19260	17.69588470	4.44	0.0155
TOTAL	-1.28	77370			

VALUES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

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Table 2. Statistics of Argentina Corn Model.

CHS	BETA1	REF1	REF2	REF3	REF4	REF5	REF6	REF7	REF8	REF9	REF10	REF11	REF12	REF13	REF14	REF15	REF16	REF17	REF18	REF19	REF20	REF21	REF22	REF23	REF24	REF25	REF26	REF27	REF28	REF29	REF30	REF31	REF32	REF33	REF34	REF35	REF36	REF37	REF38	REF39	REF40	REF41	REF42	REF43	REF44	REF45	REF46	REF47	REF48	REF49	REF50	REF51	REF52	REF53	REF54	REF55	REF56	REF57	REF58	REF59	REF60	REF61	REF62	REF63	REF64	REF65	REF66	REF67	REF68	REF69	REF70	REF71	REF72	REF73	REF74	REF75	REF76	REF77	REF78	REF79	REF80	REF81	REF82	REF83	REF84	REF85	REF86	REF87	REF88	REF89	REF90	REF91	REF92	REF93	REF94	REF95	REF96	REF97	REF98	REF99	REF100	REF101	REF102	REF103	REF104	REF105	REF106	REF107	REF108	REF109	REF110	REF111	REF112	REF113	REF114	REF115	REF116	REF117	REF118	REF119	REF120	REF121	REF122	REF123	REF124	REF125	REF126	REF127	REF128	REF129	REF130	REF131	REF132	REF133	REF134	REF135	REF136	REF137	REF138	REF139	REF140	REF141	REF142	REF143	REF144	REF145	REF146	REF147	REF148	REF149	REF150	REF151	REF152	REF153	REF154	REF155	REF156	REF157	REF158	REF159	REF160	REF161	REF162	REF163	REF164	REF165	REF166	REF167	REF168	REF169	REF170	REF171	REF172	REF173	REF174	REF175	REF176	REF177	REF178	REF179	REF180	REF181	REF182	REF183	REF184	REF185	REF186	REF187	REF188	REF189	REF190	REF191	REF192	REF193	REF194	REF195	REF196	REF197	REF198	REF199	REF200	REF201	REF202	REF203	REF204	REF205	REF206	REF207	REF208	REF209	REF210	REF211	REF212	REF213	REF214	REF215	REF216	REF217	REF218	REF219	REF220	REF221	REF222	REF223	REF224	REF225	REF226	REF227	REF228	REF229	REF230	REF231	REF232	REF233	REF234	REF235	REF236	REF237	REF238	REF239	REF240	REF241	REF242	REF243	REF244	REF245	REF246	REF247	REF248	REF249	REF250	REF251	REF252	REF253	REF254	REF255	REF256	REF257	REF258	REF259	REF260	REF261	REF262	REF263	REF264	REF265	REF266	REF267	REF268	REF269	REF270	REF271	REF272	REF273	REF274	REF275	REF276	REF277	REF278	REF279	REF280	REF281	REF282	REF283	REF284	REF285	REF286	REF287	REF288	REF289	REF290	REF291	REF292	REF293	REF294	REF295	REF296	REF297	REF298	REF299	REF300	REF301	REF302	REF303	REF304	REF305	REF306	REF307	REF308	REF309	REF310	REF311	REF312	REF313	REF314	REF315	REF316	REF317	REF318	REF319	REF320	REF321	REF322	REF323	REF324	REF325	REF326	REF327	REF328	REF329	REF330	REF331	REF332	REF333	REF334	REF335	REF336	REF337	REF338	REF339	REF340	REF341	REF342	REF343	REF344	REF345	REF346	REF347	REF348	REF349	REF350	REF351	REF352	REF353	REF354	REF355	REF356	REF357	REF358	REF359	REF360	REF361	REF362	REF363	REF364	REF365	REF366	REF367	REF368	REF369	REF370	REF371	REF372	REF373	REF374	REF375	REF376	REF377	REF378	REF379	REF380	REF381	REF382	REF383	REF384	REF385	REF386	REF387	REF388	REF389	REF390	REF391	REF392	REF393	REF394	REF395	REF396	REF397	REF398	REF399	REF400	REF401	REF402	REF403	REF404	REF405	REF406	REF407	REF408	REF409	REF410	REF411	REF412	REF413	REF414	REF415	REF416	REF417	REF418	REF419	REF420	REF421	REF422	REF423	REF424	REF425	REF426	REF427	REF428	REF429	REF430	REF431	REF432	REF433	REF434	REF435	REF436	REF437	REF438	REF439	REF440	REF441	REF442	REF443	REF444	REF445	REF446	REF447	REF448	REF449	REF450	REF451	REF452	REF453	REF454	REF455	REF456	REF457	REF458	REF459	REF460	REF461	REF462	REF463	REF464	REF465	REF466	REF467	REF468	REF469	REF470	REF471	REF472	REF473	REF474	REF475	REF476	REF477	REF478	REF479	REF480	REF481	REF482	REF483	REF484	REF485	REF486	REF487	REF488	REF489	REF490	REF491	REF492	REF493	REF494	REF495	REF496	REF497	REF498	REF499	REF500	REF501	REF502	REF503	REF504	REF505	REF506	REF507	REF508	REF509	REF510	REF511	REF512	REF513	REF514	REF515	REF516	REF517	REF518	REF519	REF520	REF521	REF522	REF523	REF524	REF525	REF526	REF527	REF528	REF529	REF530	REF531	REF532	REF533	REF534	REF535	REF536	REF537	REF538	REF539	REF540	REF541	REF542	REF543	REF544	REF545	REF546	REF547	REF548	REF549	REF550	REF551	REF552	REF553	REF554	REF555	REF556	REF557	REF558	REF559	REF560	REF561	REF562	REF563	REF564	REF565	REF566	REF567	REF568	REF569	REF570	REF571	REF572	REF573	REF574	REF575	REF576	REF577	REF578	REF579	REF580	REF581	REF582	REF583	REF584	REF585	REF586	REF587	REF588	REF589	REF590	REF591	REF592	REF593	REF594	REF595	REF596	REF597	REF598	REF599	REF600	REF601	REF602	REF603	REF604	REF605	REF606	REF607	REF608	REF609	REF610	REF611	REF612	REF613	REF614	REF615	REF616	REF617	REF618	REF619	REF620	REF621	REF622	REF623	REF624	REF625	REF626	REF627	REF628	REF629	REF630	REF631	REF632	REF633	REF634	REF635	REF636	REF637	REF638	REF639	REF640	REF641	REF642	REF643	REF644	REF645	REF646	REF647	REF648	REF649	REF650	REF651	REF652	REF653	REF654	REF655	REF656	REF657	REF658	REF659	REF660	REF661	REF662	REF663	REF664	REF665	REF666	REF667	REF668	REF669	REF670	REF671	REF672	REF673	REF674	REF675	REF676	REF677	REF678	REF679	REF680	REF681	REF682	REF683	REF684	REF685	REF686	REF687	REF688	REF689	REF690	REF691	REF692	REF693	REF694	REF695	REF696	REF697	REF698	REF699	REF700	REF701	REF702	REF703	REF704	REF705	REF706	REF707	REF708	REF709	REF710	REF711	REF712	REF713	REF714	REF715	REF716	REF717	REF718	REF719	REF720	REF721	REF722	REF723	REF724	REF725	REF726	REF727	REF728	RE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ORIGINAL PAGE IS
OF POOR QUALITY

Table 3. Results of Jackknife Test for Argentina Corn Model.

14:41 TUESDAY, MARCH

1962-1976

ARGENTINA CORN JACKKNIFE TEST OF MODEL

DETERMINED YIELD
P=MODELS PREDICTED YIELD

PLOT OF YIELD BY YIELD R SYMBOL USED IS P
PLOT OF OBSERVED YIELD R SYMBOL USED IS O

YIELD

0

P
0

0

P

0

0

P

0

0

0

0

0

P

P

0

1952 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976

YIELD

Figure 4. Argentina Corn Model.

ORIGINAL PAGE IS
OF POOR QUALITY